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CURRENT STATUS OF THRIPS (THYSANOPTERA: THIRIPIDAE) IN VIDALIA ONIONS IN GEORGIA

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ABSTRACT

The Vidalia onion crop in Georgia is grown in the winter, and the key insect pests in Georgia are thrips (Thysanoptera: Thripidae). The thrips complex consists predominantly of tobacco thrips, *Frankliniella fusca* (Hinds), with smaller percentages of western flower thrips, *F. occidentalis* Pergande, eastern flower thrips, *F. tritici* (Fitch) and onion thrips, *Thrips tabaci* Lindeman. Onion thrips has become a greater concern in the last 10 years likely due to the introduction of a more aggressive biotype of *T. tabaci* on onions coming from Peru into the Vidalia region. A preliminary laboratory bioassay at 25 °C suggested that this onion thrips biotype could out-compete tobacco thrips on onions. Surveys were conducted from 2004 through 2013 in commercial Vidalia onion fields to determine if this increase in the percentage of onion thrips would occur. Average seasonal temperatures were highly correlated ($r = 0.811$) with percent *T. tabaci* and negatively correlated ($r = -0.807$) with *F. fusca*. The results suggest that temperature might regulate the proportion of onion thrips to tobacco thrips in the field, with a higher percentage of tobacco thrips occurring during cool winters and more onion thrips occurring in warm winters. Nevertheless, *F. fusca* continues to be the dominant thrips species in the Vidalia onion winter growing region of Georgia averaging 78% of the adult thrips population from 2004 to 2013.

Key Words: Thysanoptera, *Thrips tabaci*, *Frankliniella fusca*, onions, vegetable IPM

RESUMEN

El cultivo de cebolla de Vidalia se cosecha en Georgia en el invierno, y las plagas de insectos importantes en Georgia son los trips (Thysanoptera: Thripidae). El complejo de trips consiste principalmente del trips de tabaco, *Frankliniella fusca* Hinds, con porcentajes menores del trips occidental de las flores, *F. occidentalis* Pergande, del trips de las flores, *F. tritici* (Fitch) y del trips de la cebolla, *Thrips tabaci* (Linderman). El trips de la cebolla en los últimos 10 años se ha convertido en una preocupación mayor probablemente debido a la introducción de cebollas del Perú desde el año 2003 de un biotipo más agresivo de *T. tabaci* en la región de Vidalia. Un bioensayo preliminar a 25 °C en el laboratorio indicó que el biotipo del trips Peruano de la cebolla puede competir mejor los trips del tabaco sobre las cebollas. Se realizaron sondeos entre 2004 y 2013 en los campos comerciales de cebolla Vidalia para determinar si este aumento en el porcentaje de trips de la cebolla se presentaría. El promedio de las temperaturas estacionales fuer altamente correlacionado ($R = 0.811$) con el por ciento de *T. tabaci* y negativamente correlacionado ($R = -0.807$) con *F. fusca*. Los resultados sugieren que la temperatura podría regular la proporción de trips de la cebolla a los trips de tabaco en el campo, con un porcentaje mayor de trips de tabaco durante inviernos fríos y más trips de la cebolla durante los inviernos más calidos. Sin embargo, *F. fusca* sigue siendo la especie de trips dominante en la región de cultivo de cebolla Vidalia de Georgia en invierno con un promedio de 78 % de la población de trips adultos desde el 2004 hasta el 2013.

Palabras Clave: Thysanoptera, *Thrips tabaci*, *Frankliniella fusca*, cebollas, MIP en hortalizas

Thrips, particularly the onion thrips, *Thrips tabaci* Lindeman, are important insect pests of onions throughout the world (Diaz-Montano et al. 2011). The Vidalia onion production region in Georgia, which consists of ~13,000 acres valued

at \$126,000,000 (Boatwright & McKissick 2009), is an unusual onion production region because the dominant species attacking onions has traditionally been tobacco thrips, *Frankliniella fusca* (Hinds) (Sparks et al. 2011). By comparison, *T.*

tabaci is predominant in New York (Nault & Shelton 2010), Canada (Fournier et al. 1995), Texas (Edelson et al. 1989), Colorado (Mahaffey & Cranshaw 2010), New Zealand (Jamieson et al. 2012), Israel (Lebedev et al. 2013), Italy (Mautino et al. 2012), Pakistan (Ullah et al. 2010) and in other parts of the world (Diaz-Montano et al. 2011). Thrips are the most damaging insect in onions in Georgia (Sparks & Riley 2008, Sparks et al. 2011). Natural enemies of thrips in onions likely do not provide sufficient control (Liu 2004).

Significant damage to onions by thrips can range from 30% (Rueda et al. 2007), 35-43% (Fournier et al. 1995), to 60% yield loss (Waiganjo et al. 2008). Action and/or economic threshold calculations have been based on dollar yield response (Fournier et al. 1995) and onion leaf damage estimates (Nault & Shelton 2010). These thrips control action thresholds do not take into account the potential impact of *Iris yellow spot virus* (IYSV) transmission by thrips, which can significantly reduce yields of jumbo and colossal sizes of onion (Kritzman et al. 2001; Gent et al. 2004). Most thresholds are based on thrips per onion leaf (Fournier et al. 1995, Rueda et al. 2007, Nault & Shelton 2010). However, since most damage by thrips occurs at the beginning of the bulb formation stage (Kendall & Capinera 1987), which occurs during the 8-12 leaf stage (Schwartz & Cramer 2011), a simple estimate of an action threshold for thrips per plant during this critical onion development stage would be the thrips per leaf level of 0.9 (Fournier et al. 1995) multiplied by 8 to 12 = 7 to 11 thrips per plant. In Georgia's Vidalia onion production area, insecticide applications are recommended at an action threshold of 5 thrips per plant (Sparks & Riley 2008) as a slightly more conservative level.

During the last decade, greater numbers of *T. tabaci* have been found in the Vidalia onion region, presumably due to *T. tabaci*-contaminated onion bulbs imported from Peru to the Vidalia region beginning in 2003 (Sparks et al. 2011). Sweet onions are grown in Peru during the spring and summer months and shipped to Georgia so that Vidalia onion processing/packing sheds can remain active in the fall of the year, after the Vidalia onion storage crop is exhausted. In 2004, the composition of thrips species from a major onion cull pile was compared to the composition of thrips species collected from surrounding commercial fields in the subsequent onion growing season to test this assertion. Subsequently, thrips competition studies were conducted in a laboratory bioassay in 2004 to determine if the Peruvian *T. tabaci* would reproduce at a greater rate on onion plants than *F. fusca* at 25 °C in single species populations or when multiple species are combined on the same onion plant. The hypothesis was that *T. tabaci* would out-compete *F. fusca* on onion. Based on the preliminary result reported in this

paper, we hypothesized that the proportion of *T. tabaci* relative to *F. fusca* should increase in the Vidalia region. A 10-year survey was conducted to monitor the proportion of *T. tabaci* to other thrips species across multiple commercial fields within the Vidalia production region. Correlation analysis was conducted to determine if annual winter temperatures varied the same way as the proportion of thrips species.

MATERIALS AND METHODS

Thrips Competition Study

Onion transplants (cultivar 'Savannah Sweet') of "pencil" thickness and at a 3-5 leaf stage free of thrips based on visual inspection were planted into soil media (Sunshine Mix, Sun Gro Horticulture, Bellevue, Washington) in a 1 quart (0.946 L) styrofoam cup and sprayed to run-off with 1% Safer® Soap solution. After 24 h on 8 Apr, 2004, thrips were placed on the plant with a fine paint brush, and a quart-cup plastic exclusion cage covered with a fine nylon screen top vent was placed over the styrofoam cup. The edge between the cups was sealed with a sticky clay strip (yellow Handitak, Pacer Technology, Cucamonga, California). All thrips were reared on onion plants in an established colony before collection, and both the *T. tabaci* colony and *F. fusca* colony were > 90% female at the time of the test. The treatments were: 1) ten *T. tabaci* pupae, 2) ten *F. fusca* pupae, and 3) ten *F. fusca* pupae + ten *T. tabaci* pupae. These were pupal stages so that the individuals would eclose as adults at approximately the same time. There were 4 replications, and the experiment was repeated twice. All of the cups were placed into a Percival Growth Chamber, 2 replicates per each shelf, and the temperature was set to 27.5 °C and 12:12 h L:D. The cages were maintained undisturbed for 1 week, and then the top cup was removed. The entire plant and cup was inspected for adults (presumably from the introduced pupae) and any newly hatched immature thrips that might be present. All adult thrips were removed and placed into 70% ethanol in 7-mL vials with treatment and date labels. Only immature thrips were counted. The cages were sealed leaving immature thrips for another 2 weeks, and the above procedure was repeated. The above procedure was repeated 2 more times 1 week apart, and in the final inspection all thrips adults and larvae were counted and collected into 70% ethanol. All adult thrips were identified to species using identification keys (Oetting et al. 1993; Stannard 1968) at 70-140X magnification by a SZH10 Olympus® (Olympus America, Lake Success, New York) stereomicroscope. Analysis of variance and LSD tests for separation of treatment means (SAS Institute 1990) were performed by sample date and the means were summed over all dates. The com-

petition experiments were combined because of similar treatment effects and PROC ANOVA was conducted over all 8 replicates.

Onion Cull Pile Survey

Sprouted bulbs at a large cull pile of Peruvian onions near a major onion processing plant in Tattnall county were monitored for thrips species composition during the fall 2003 to spring 2004 season on 16 Dec, 3 Feb, 10 Mar, 7 Apr. Eight commercial onion production fields were sampled within Toombs and Tattnall counties from approximately 5 to 50 miles (8 to 80 km) from the cull pile site on 3 and 17 Mar and 7 Apr. At each site, on each sample date, plants were visually examined for thrips. Plants were randomly selected, and sampling was conducted for approximately 30 min in each field on each date (one person sampling for 30 min, or 2 sampling for 15 min). Thrips were aspirated off the plants and placed into alcohol. All thrips collected were examined to determine developmental stage (adult or immature) and species. The majority of thrips collected were adults, and only the adult data are presented. Adult thrips were examined under a dissecting scope for preliminary species identification. Subsamples were mounted on slides and examined under a compound microscope for species verification. A *t* test was used to describe the variation in percent *T. tabaci* of all adult thrips collected between cull pile and onion production field sites.

Commercial Onion Survey

Onion production fields were sampled within Toombs and Tattnall counties from spring 2004 through spring 2013 exactly as described by Sparks et al. (2011). The data for percent *T. tabaci* across all location was from the Sparks et al. (2011) study plus sample years 2011-2013. In each year, fields selected were scattered throughout these 2 counties. In 2004, 8 fields were sampled, with 4 in each county, with data from 3 dates (3 and 17 Mar, 7 Apr). In 2005, ten commercial fields were sampled, with 5 fields in each county, over 5 dates (11 and 22 Feb, 14 Mar, 4 and 27 Apr). In 2006, 9 fields were sampled, with 4 in Toombs County and 5 in Tattnall County. These fields were sampled 5 times (19 Jan, 7 and 27 Feb, 16 and 28 Mar). In 2007, eleven fields were sampled on 13 Mar. Based on the results from these fields, additional sampling of 18 fields from 2 through 10 Apr was conducted to further document an increase in *T. tabaci*. In 2008, 16 fields were sampled between 8 and 11 Apr. In 2009, 14 fields were sampled on 25 Mar. In 2010, 18 fields were sampled on 6 May. In 2011, 15 fields were sampled on 11 Apr. In 2012, 10 fields were sampled on 8 Mar, and in 2013, 23 fields were sampled between 13 Mar and 24 Apr.

Percent *T. tabaci* and *F. fusca* per year was calculated based on adult thrips counts.

In each field on each sample date, plants were visually observed for thrips, and adults were aspirated into vials of 70% ethanol. Each field was sampled for 30 min when populations were low to moderate. If thrips populations were high and adequate numbers of adults were collected, sample time was reduced. All thrips were transported to the laboratory for identification. Thrips were preliminarily identified and counted under a dissecting microscope. Subsamples of each species were slide mounted for verification. Voucher specimens were sent to the University of Georgia-Museum of Natural History. While multiple species were collected during this monitoring program, only the common pest species, *F. fusca* and *T. tabaci*, were included in this report. These 2 species, *F. fusca* and *T. tabaci*, represented over 95% of all thrips collected each year.

Weather data, including the daily maximum and minimum temperatures and precipitation from Nov 1 to May 1 of each annual, onion-growing season from transplant to harvest, were obtained from the Georgia Automated Weather Station at Vidalia, Toombs County, Georgia (<http://www.griffin.uga.edu/aemn/cgi-bin/AEMN.pl?site=GAVI&report=hi> accessed Nov 25, 2013). The average temperature calculated as the (daily high + daily low)/2 and total rainfall values from Nov 1 to May 1 for the years 2003-2013 were correlated with annual percentages of thrips species to see if temperature and/or rainfall during the growing season were related to the annual percentage of a given thrips species over years ($n = 10$) using PROC CORR (SAS Institute 1990).

RESULTS AND DISCUSSION

Thrips Competition Study

Thrips tabaci and *F. fusca* reproduced similarly on onions based on numbers of larvae produced by each species (Table 1). *Thrips tabaci* produced 22% more adults overall. When combined (ten *F. fusca* pupae + ten *T. tabaci* pupae per plant), *F. fusca* produced significantly fewer adults than when *F. fusca* alone was present on the plant, whereas *T. tabaci* had no significant reduction in adults at date or overall (Table 1). There was a significant reduction in the overall number of nymphs ($F = 6.73$, $df = 2, 14$, $P < 0.01$, Table 1) on the plants where the 2 species were combined. This suggests that mortality of immature thrips was elevated when thrips species were combined possibly due to some direct competition. Given that the number of *T. tabaci* adults was unaffected after one generation and the number of *F. fusca* adults was significantly reduced in the combined treatment, the most likely scenario was that *T.*

TABLE 1. NUMBERS OF THRIPS EMERGING FROM ONION PLANTS BEGINNING ONE WEEK AFTER THE REMOVAL OF ADULTS FROM AN INITIAL INFESTATION OF 10 PUPAE OF *T. TABACI*, 10 PUPAE OF *F. FUSCA*, OR 10 PUPAE OF BOTH SPECIES COMBINED ON THE SAME PLANT UNDER CONSTANT CONDITIONS OF 25 °C AND 12:12 H L:D IN A GROWTH CHAMBER.

Treatment	Week 1			Week 2			Summed Overall		
	Adult <i>F. fusca</i>	Adult <i>T. tabaci</i>	Larvae	Adult <i>F. fusca</i>	Adult <i>T. tabaci</i>	Larvae	Adult <i>F. fusca</i>	Adult <i>T. tabaci</i>	Larvae
<i>T. tabaci</i>	0.0 b*	1.3 a	11.5 a	0.0 b	7.3 a	20.0 a	0.0 b	26.8 a	54.6 a
<i>F. fusca</i>	1.5 a	0.0 b	5.6 a	3.8 a	0.0 b	17.6 a	21.0 a	0.0 b	50.8 a
<i>T. tabaci</i> + <i>F. fusca</i>	0.1 b	1.5 a	2.3 a	1.0 ab	11.5 a	0.75 b	2.9 b	25.0 a	13.6 b

*Means in columns followed by the same letter are not significantly different (LSD, *P* > 0.05).

tabaci interfered with the development of immature stages of *F. fusca*.

Onion Cull Pile Survey

In the first year of the survey, 2003-2004, the percentage of *T. tabaci* to total adult thrips in the onion cull piles compared to 8 different onion field sites in the surrounding counties (Fig. 1) was 60 ± 22% (*n* = 4) and 5 ± 5% (*n* = 22), respectively (*t* = 2.06, *df* = 24, *P* < 0.05). Conversely, the percentage of *F. fusca* to total adult thrips in the onion

cull piles compared to 8 different onion field sites in the surrounding counties was 40 ± 22% (*n* = 4) and 84 ± 7% (*n* = 22), respectively (*t* = 2.06, *df* = 24, *P* < 0.05). Cull piles of Peruvian sweet onions harbored proportionally 12 × more *T. tabaci* than surrounding onion production fields.

Commercial Onion Survey

The average thrips species composition in the multi-site, 10-year survey of commercial onion production fields was 78% tobacco thrips, *F. fusca*,

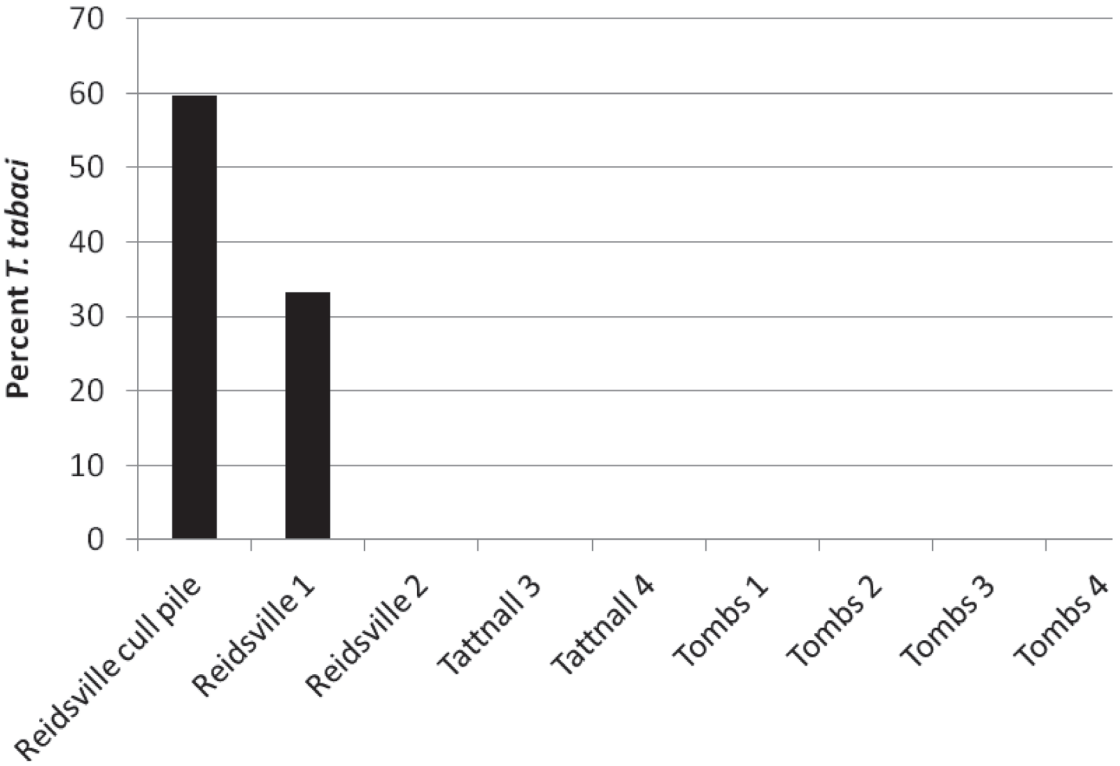


Fig. 1. Percentage of *T. tabaci* of all adult thrips collected in onion cull piles near Reidsville, Georgia in Tattnall County compared to eight commercial onion field locations in Tattnall and Tombs Counties in 2003-2004.

based on adult counts over all locations and years (Fig. 2). The flower thrips, *F. occidentalis* Pergande and *F. tritici* (Fitch), represented less than 2% over this 10-year survey. *Thrips tabaci* represented 20% of the adult thrips population (Fig. 2). This was a change from the less than 1% *T. tabaci* reported for onions in Georgia from 1998 to 2001 (Riley & Batal 1997, 1998; Riley 2000, 2001), who also reported *F. fusca* as the dominant species, averaging 62% of the adult thrips population over the 4 years, followed by *F. occidentalis* 28% and *F. tritici* 10%. These reports were from Tift County which is south of the main Vidalia onion production region in Toombs and Tattnall Counties.

During the first 3 years of this survey, the proportion of *T. tabaci* tended to decline, but in 2007 the population suddenly exceeded 50% of the adults collected (Fig. 2). The percentage of *T. tabaci* again declined from 2008 to 2011 and then again in 2012 spiked up to 64% of the adult thrips collected. This last increase coincided with one of the warmest years on record for Georgia, which suggested that temperature could be a factor in the relative proportion of thrips species in onion. The percentage of *T. tabaci* was positively correlated ($r = 0.811$, $P < 0.01$, $n = 10$) with the seasonal average temperature in the Vidalia onion growing region from 2004 to 2013. Conversely, the percentage of *F. fusca* was negatively correlated with the seasonal average temperature ($r = -0.807$, $P < 0.01$, $n = 10$). Over this same period, *F. fusca* was positively correlated with total adult thrips ($r =$

0.933 , $P < 0.001$, $n = 10$), but *T. tabaci* was not ($r = 0.090$, $P = 0.80$, $n = 10$) suggesting that the peaks of *T. tabaci* were less indicative of overall thrips populations on onions in this specific winter production zone.

The results of this study indicate an obvious change in the pest thrips species complex over time, likely related to differences in temperature. In the 10 years of this study, flower thrips had declined to less than 2% of the adult population in commercial onion fields (compared to the previously reported 38% in 1997-2001). *Thrips tabaci* sporadically increased to a 2012 high of 64% (averaging 20% from 2004-2013), and *F. fusca*, the tobacco thrips, remained the dominant species for most years (averaging 78% from 2004-2013).

Several other factors likely contributed to the observed fluctuations in thrips species composition in Vidalia onion over the last decade. It is likely that a new biotype of the onion thrips established in this region (Sparks et al. 2011). Genetic analyses of *T. tabaci* from the Vidalia region in recent years do not exclude Peru as a possible source of its introduction (Srinivasan et al. 2011). The competition studies conducted with the *T. tabaci* collected from Peruvian onion cull piles indicate that this species has the potential to successfully compete with the *F. fusca* under warm conditions (25 °C). However, *F. fusca* seems to be favored by cool temperatures, as indicated by the negative correlation with winter temperatures in this study, which is characteristic of the Vida-

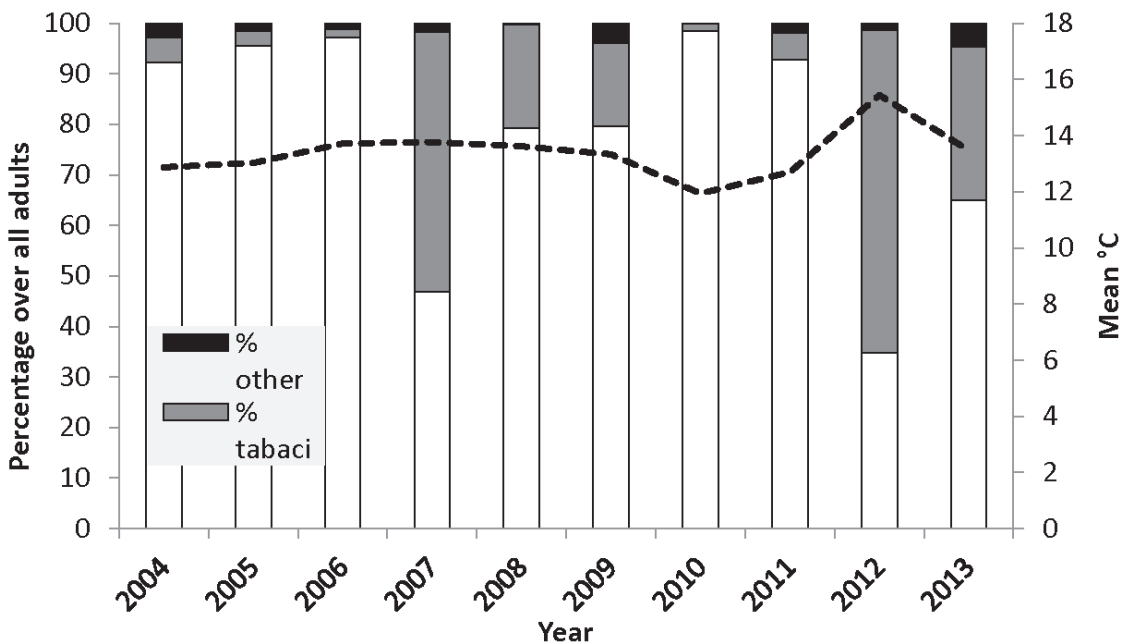


Fig. 2. Percentage of *F. fusca*, *T. tabaci* and other thrips adults (predominantly *F. occidentalis* and *F. tritici*) over all sample locations in the Vidalia onion region of Georgia contrasted with the average temperature in this region from Nov 1 to May 1 each year.

lia onion growing season between Nov and May each year. Insecticide resistance may have also played a role in the population shift. Lack of efficacy of organophosphate insecticides against the *F. fusca* and *F. occidentalis* in Georgia detected in the early 2000s (Riley 2001) resulted in a shift in insecticide use toward pyrethroid insecticides. Onion thrips is well known for pyrethroid resistance in much of its range (Martin et al. 2003; MacIntyre-Allen et al. 2005; Shelton et al. 2006), and field trials conducted in the Vidalia region in 2007 verified poor performance against the onion thrips and continued good efficacy against tobacco thrips (Sparks 2008). Concerns over the potential impact of IYSV led to increased reliance on insecticides for control of the thrips vector in 2006 and 2007 (Sparks, personal observation). Thus, the increased use of pyrethroid insecticides in the region may be partially responsible for the observed shift. In 2008, a decline in pyrethroid efficacy against tobacco thrips was noted in field trials (Sparks unpublished data). This, in combination with reduced use of insecticides, may have removed part of the competitive advantage of the onion thrips and contributed to the shift back towards historical pest complex composition. Even so, the positive correlations with temperature suggest that *T. tabaci* may be favored in warmer years.

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REFERENCES CITED

- BOATRIGHT, S. R., AND MCKISSICK, J. C. 2009. 2008 Georgia Farm Gate Vegetable Report. <http://www.caes.uga.edu/center/caed/pubs/2009/documents/AR-09-02.pdf>. Accessed 26-XI-2013.
- DIAZ-MONTANO, J., FUCHS, M., NAULT, B. A., FAIL, J., AND SHELTON, A. M. 2011. Onion Thrips (Thysanoptera: Thripidae): A global pest of increasing concern in onion. *J. Econ. Entomol.* 104: 1-13.
- EDELSON, J. V., CARTWRIGHT, B., AND ROYER, T. A. 1989. Economics of controlling onion thrips (Thysanoptera, Thripidae) on onions with insecticides in south Texas. *J. Econ. Entomol.* 82: 561-564.
- FOURNIER, F., BOIVIN, G., AND STEWART, R. K. 1995. Effect of *Thrips-tabaci* (Thysanoptera, Thripidae) on yellow onion yields and economic thresholds for its management. *J. Econ. Entomol.* 88: 1401-1407.
- GENT, D. H., SCHWARTZ, H. F., AND KHOSLA, R. 2004. Distribution and incidence of Iris yellow spot virus in Colorado and its relation to onion plant population and yield. *Plant Dis.* 88: 446-452.
- JAMIESON, L. E., CHHAGAN, A., AND GRIFFIN, M. 2012. Temperature development and damage rates of onion thrips. *New Zealand Plant Protection* 65: 126-132.
- KENDALL, D. M., AND CAPINERA, J. L. 1987. Susceptibility of onion growth-stages to onion thrips (Thysanoptera, Thripidae) damage and mechanical defoliation. *Environ. Entomol.* 16: 859-863.
- KRITZMAN, A., LAMPEL, M., RACCAH, B., AND GERA, A. 2001. Distribution and transmission of *Iris yellow spot virus*. *Plant Dis.* 85: 838-842.
- LEBEDEV, G., ABO-MOCH, F., GAFNI, G., BEN-YAKIR, D., AND GHANIM, M. 2013. High-level of resistance to spinosad, emamectin benzoate and carbosulfan in populations of *Thrips tabaci* collected in Israel. *Pest Mgt. Sci.* 69: 274-277.
- LIU, T. X. 2004. Seasonal population dynamics, life stage composition of *Thrips tabaci* (Thysanoptera: Thripidae), and predaceous natural enemies on onions in south Texas. *Southwest Entomol.* 29: 127-135.
- MAHAFFEY, L. A., AND CRANSHAW, W. S. 2010. Thrips species associated with onion in Colorado. *Southwest Entomol.* 35: 45-50.
- MACINTYRE-ALLEN, J. K., SCOTT-DUPREE, C. D., TOLMAN, J. H., AND HARRIS, C. R. 2005. Resistance of *Thrips tabaci* to pyrethroid and organophosphorus insecticides in Ontario, Canada. *Pest Mgt. Sci.* 61: 809-815.
- MARTIN, N. A., WORKMAN, P. J., AND BUTLER, R. C. 2003. Insecticide resistance in onion thrips (*Thrips tabaci*) (Thysanoptera: Thripidae). *New Zealand J. Crop and Hort. Sci.* 31: 99-106.
- MAUTINO, G. C., BOSCO, L., AND TAVELLA, L. 2012. Integrated management of *Thrips tabaci* (Thysanoptera: Thripidae) on onion in north-western Italy: basic approaches for supervised control. *Pest Mgt. Sci.* 68: 185-193.
- NAULT, B. A., AND SHELTON, A. M. 2010. Impact of insecticide efficacy on developing action thresholds for pest management: a case study of onion thrips (Thysanoptera: Thripidae) on onion. *J. Econ. Entomol.* 103: 1315-1326.
- OETTING, R. D., BESHEAR, R. J., LIU, T. X., BRAMAN, S. K., AND BAKER, J. R. 1993. Biology and identification of thrips on greenhouse ornamentals. *Research Bull.* 414. Georgia Agric. Exp. Stn.
- RILEY, D. G., AND BATAL, K. 1997. Management of thrips on onions, pp. 41-42. *In* Georgia Onion Res.-Ext. Report 1996-97. Univ. Georgia, Coop. Res.-Ext. Publ. No. 3-98.
- RILEY, D. G., AND BATAL, K. 1998. Onion cultivar response to thrips infestation, pp. 52-57. *In* Georgia Onion 1998 Research-Extension Rep. Univ. Georgia, Coop. Res.-Ext. Publ. No. 3-99.
- RILEY, D. G. 2000. Thrips control in onions, pp 51-53. *In* Georgia Onion 2000 Res.-Ext. Rep. Univ. Georgia, Coop. Res.-Ext. Publ. No. 3-2001.
- RILEY, D. G. 2001. Thrips control in onions, pp 36-38. *In* Georgia Onion 2001 Res.-Ext. Rep. Univ. Georgia, Coop. Res.-Ext. Publ. No. 3-2002.
- RUEDA, A., BADENES-PEREZ, F. R., AND SHELTON, A. M. 2007. Developing economic thresholds for onion thrips in Honduras. *Crop Prot.* 26: 1099-1107.
- SAS INSTITUTE. 1990. SAS user's guide, version 6, SAS Institute, Cary, NC.

- SCHWARTZ, H. F., AND CRAMER, C. S. 2011. Bulb growth stages of onion. Onion IPMPIPE. Diagnostic Pocket Series. <http://apps.planalytics.com/aginsights/pipe-home.jsp?detail=stages> accessed Nov 27, 2013.
- SHELTON, A. M., ZHAO, J. Z., NAULT, B. A., PLATE, J., MUSSER, F. R., AND LARENTZAKI, E. 2006. Patterns of insecticide resistance in *T. tabaci* (Thysanoptera: Thripidae) in onion fields in New York. *J. Econ. Entomol.* 99: 1798-1804.
- SPARKS, A. N., AND RILEY, D. G. 2008. Onion insects and their control, pp. 28-31 *In* G. E. Boyhan and W. T. Kelley [eds.], *Onion Production Guide*, Univ. Georgia, Coop. Ext. Publ. No. B 1198-2.
- SPARKS, A. N. 2008. Control of thrips on onions, 2007. pp. 15-17 *In* 2007 Georgia Onion Res.-Ext. Annu. Rep. Univ. Georgia, Coop. Res.-Ext. Publ. No. 3-2007.
- SPARKS, A. N., DIFFIE, S., AND RILEY, D. 2011. Thrips species composition on onions in the Vidalia production region of Georgia. *J. Entomol. Sci.* 46: 1-6.
- SRINIVASAN, R., GUO, F., RILEY, D., DIFFIE, S., GITAITIS, R., SPARKS, A., AND JEYAPRAKASH, A. 2011. Assessment of variation among *Thrips tabaci* populations from Georgia and Peru based on polymorphism in mitochondrial cytochrome oxidase I and ribosomal ITS2 sequences. *J. Entomol. Sci.* 46: 191-203.
- STANNARD, L. J. 1968. The Thrips, or Thysanoptera of Illinois. Illinois Natural History Survey Bull. 29 (article 4) 431: 483-490. Urbana IL.
- ULLAH, F., MARAJ-UL-MULK, FARID, A., SAEED, M. Q., AND SATTAR, S. 2010. Population dynamics and chemical control of onion thrips (*Thrips tabaci*, Lindemann). *Pakistan J. Zool.* 42: 401-406.
- WAIGANJO, M. M., MUEKE, J. M., AND GITONGA, L. M. 2008. Susceptible onion growth stages for selective and economic protection from onion thrips infestation, pp. 193-199 *In* R. K. Prange and S. D. Bishop [eds.], *Proc. Intl. Symp. Sustainability Through Integrated and Organic Horticulture*, Book Series: Acta Hort. 767.